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(54) **Titre : PROCÉDE DE REPARATION DE COMPOSANT D'ALLIAGE D'ALUMINIUM**
(54) **Title: METHOD FOR REPAIRING AN ALUMINIUM ALLOY COMPONENT**

(57) **Abrégé/Abstract:**

The invention refers to a method for the repair of an aluminium alloy component, in particular a precipitation-hardened aluminium alloy component, comprising the steps of: a) depositing by cold spray on said component to be repaired a portion of supplied material, thus obtaining a partially repaired component; b) subjecting said partially repaired component to a thermal treatment, thus obtaining a repaired component, the conditions of performance of said thermal treatment being selected according to the composition and dimensional tolerances of said component.

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(54) Title: METHOD FOR REPAIRING AN ALUMINIUM ALLOY COMPONENT

(57) Abstract: The invention refers to a method for the repair of an aluminium alloy component, in particular a precipitation-hardened aluminium alloy component, comprising the steps of: a) depositing by cold spray on said component to be repaired a portion of supplied material, thus obtaining a partially repaired component; b) subjecting said partially repaired component to a thermal treatment, thus obtaining a repaired component, the conditions of performance of said thermal treatment being selected according to the composition and dimensional tolerances of said component.

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"METHOD FOR REPAIRING AN ALUMINIUM ALLOY COMPONENT"TECHNICAL FIELD

The present invention concerns a method for repairing an
5 aluminium alloy component, in particular a precipitation-
hardened aluminium alloy component.

BACKGROUND ART

As is known, aeronautical components, in general, are
10 subjected during use to high levels of mechanical stress and
must therefore have specific mechanical properties, in
particular in terms of mechanical resistance at high
temperature, hardness and wear resistance.

15 In particular, this need is felt for components such as
accessory or power transmission housings for aeronautical and
helicopter engines. Said components are typically made of
precipitation-hardened lightweight aluminium alloys.

20 Frequently, said components need repairs. This can occur in
the various manufacturing phases of new components, for
example at the level of production of the castings, semi-
finished products or after a machining phase, for dimensional
reasons or due to local damage resulting from handling or
25 transport, or due to metallurgical defects such as porosity,
cracks or inclusions. Moreover, finished components frequently
have to be repaired after a period of operation due to
problems of wear, corrosion, undesired impacts or other.

30 Traditionally, repair of aluminium alloy components is carried
out using various technologies including: repair by deposit of
weld material (TIG welding, laser cladding, etc.); application
of high resistance resins; interference fit (for recovery of
oversized internal diameters by means of bushing); depositing
35 techniques by thermal spraying.

Said technologies have various drawbacks, as will be illustrated below.

Repair techniques based on welding are widely used for the repair of rough components prior to heat treatment. They have the undoubted advantage of producing a metallurgical link with the material of the substrate, but they are difficult to apply to the repair of components that have already been machined, due to the deformations produced by the welding. Furthermore, in particular for precipitation-hardened aluminium alloys, the weld material has a very different microstructure and significantly inferior mechanical properties with respect to the substrate.

The repair techniques by application of high resistance polymeric resins have limited applicability due to the evident dissimilarity between the metallic base material and the supplied material, which consists substantially of an organic resin. The high polymerisation temperatures of some epoxy type resins, which can be in the order of 200°C, moreover, can cause an undesirable deterioration in the mechanical characteristics of some precipitation-hardened lightweight alloys.

The repair techniques based on interference fit are usually used for recovering worn or oversized internal diameters, but this type of application is evidently limited by geometric and structural factors.

Repair of components made of aluminium or relative alloys by means of thermal spraying techniques entails depositing of supplied material in which the particles of the material to be deposited are brought to a high temperature which causes them to melt. This technology consequently has the disadvantage, as regards the depositing of aluminium powder, of favouring oxidisation of the melted particles in contact with the

atmospheric oxygen.

Furthermore, the mechanical properties of the portion of supplied material are decidedly inferior to those of the substrate, and also the quality of the relative adhesion is
5 generally unsatisfactory.

To remedy this drawback, thermal spraying for repair of aluminium alloys is often performed by depositing materials
10 different from the base material. Bronze powders or Ni-Al alloys are often used. However, the application of materials different from the base material entails other problems connected with the different behaviour of dissimilar materials during the component manufacturing completion processes (for
15 example in the case of application of the anode oxidisation process of the aluminium component) or during operation (for example due to effects of accelerated galvanic corrosion, differential thermal expansion coefficients, etc.).

20 A further disadvantage of the repair techniques by traditional thermal spraying processes (plasma spray, HVOF, thermo-spray, D-gun, etc.) derives from the fact that the substrate temperature must be very carefully monitored to avoid excessive temperatures being reached with consequent possible
25 deterioration of the mechanical properties. It is known, in fact, that aluminium alloys, in particular those hardened by precipitation of hardening phases, can rapidly lose their characteristics of tensile strength and yield strength following heating to temperatures higher than the
30 precipitation temperatures.

The need is therefore felt in the sector to provide a method for the repair of aluminium alloy components, in particular precipitation-hardened aluminium alloy components, which
35 overcomes at least one of the drawbacks described previously.

More specifically the need is felt, especially in the aeronautical sector, to provide a method for the repair of aluminium alloy components which gives the repaired components mechanical characteristics that meet the requirements of the particular conditions of use, with particular reference to the uniformity of the properties between the material forming the support (or the component to be repaired) and the portion of supplied material, and their relative adhesion.

Furthermore, the need is felt in the sector to provide a method for the repair of aluminium alloy components, in particular precipitation-hardened aluminium alloy components, which requires low plant investment and reduced management and maintenance costs and which can guarantee high productivity.

15

DISCLOSURE OF INVENTION

The object of the present invention is therefore to provide a method for the repair of aluminium alloy components, in particular precipitation-hardened aluminium alloy components, said method meeting simply and economically at least one of the above-mentioned needs.

20

According to one aspect, there is provided a method for repairing a precipitation hardened aluminium alloy component comprising the steps of:

a) cold spray depositing on the component to be repaired a portion of supplied material having a composition identical to that of the component to be repaired, thus obtaining a partially repaired component;

b) subjecting the partially repaired component to a thermal treatment, thus obtaining a repaired component, the conditions for performing the thermal treatment being selected as a function of the composition and of dimension tolerances of the component,

characterised in that the step b) of thermal treatment comprises:

c) a first step of solubilisation followed by cooling in water; and

d) a second step, following the first step c), of precipitation.

BEST MODE FOR CARRYING OUT THE INVENTION

For a better understanding of the present invention, a preferred embodiment thereof is described below, purely by way of non-limiting example.

Advantageously, an aluminium alloy component and, in particular, a precipitation-hardened aluminium alloy component, is repaired by depositing by cold spray a portion of supplied material on the component to be repaired, thus 35 obtaining a partially repaired component.

In the context of the invention, "component to be repaired" indicates an aluminium alloy component which requires repair, regardless of the machining state of said component.

5 "Regardless of the machining state of said component" indicates that the component to be repaired can be, with reference to the relative manufacturing process: in the rough state; in the state of a semi-finished product; finished; or even a finished component which has already been operating and
10 which requires repair to remedy damage sustained during operation *in situ*.

The "component to be repaired" constitutes the substrate of the cold spray depositing phase, which will be described in
15 greater detail below.

Following the step of depositing the portion of supplied material on the component to be repaired, a "partially repaired component" is obtained.

20 Cold spray depositing is a relatively recent technique which entails the depositing of metallic materials in the form of powder. Unlike the thermal spraying processes, however, in cold spray depositing the supplied material remains in the
25 solid state without ever reaching the melting conditions.

Typically, according to this technique, a metallic powder or a mixture of metallic powders having a pre-defined composition is injected via a nozzle and applied to a substrate,
30 undergoing acceleration in the non-melted state, at speeds in the order of $300 \div 1,200$ m/s by means of a flow of carrier gas which crosses the nozzle. Impacting with the substrate with sufficient kinetic energy, the particles of the powder locally deform the substrate and are themselves deformed.

35 In the context of the invention, the component to be repaired

forms the "substrate" on which the metallic powder is deposited constituting a "portion of supplied material".

Preferably, the metallic powder or mixture of metallic powders
5 used for depositing the portion of supplied material has a composition substantially identical to that of the substrate (i.e. the component to be repaired). The use of supplied material with composition substantially identical to that of the substrate has the advantage of minimising the differences
10 in behaviour between the substrate and the supplied material, restoring as far as possible the conditions of the repaired component with respect to the new component.

For physical and chemical-physical reasons, the technique of
15 cold spray depositing favours the formation of a portion of supplied material which is compact and securely adhering to the substrate. In particular, this advantageous result is promoted by the reciprocal interpenetration of supplied material and substrate and the breakage, at the moment of
20 impact, of the fine surface layers of oxide which, in practice, are always present in the materials exposed to the external atmosphere.

This aspect is particularly advantageous in the case of repair
25 of components damaged during operation, or when they have been exposed for a prolonged period to aggressive atmospheric conditions.

Typically, in the cold spray depositing technique, a
30 compressed gas flow at a pressure of approximately 5÷50 bars is used. This gas flow envelops the particles of metallic powder and entrains them, expelling them through the nozzle at high speed. Optionally, at least a part of the gas flow is heated before arriving at the application nozzle.

35

Preferably, a monatomic inert gas such as helium is used as

the carrier gas. Helium has the twin advantage of allowing, as a monatomic gas, acceleration of the particles at the highest speeds and simultaneously, due to its inertia, excluding the possibility of oxidisation of the metallic powder. However, since the contact times between the components of the mixture of metallic powders and the carrier gas are very limited, it is also possible to use cheaper carrier gases, such as nitrogen or air, although, at the same pressure, the speeds that can be reached by the particles are inferior to those that can be reached with helium.

The depositing temperature is typically the lowest possible, compatibly with the need to obtain a minimum level of deformation of the sprayed powder particles.

The mean dimension of the metallic particles forming the powder to be deposited can be advantageously chosen in the range between 1 and 200 μm .

This technique therefore favours by nature the formation of a portion of supplied material having a low porosity level and good adhesion characteristics vis-à-vis the material constituting the support.

In the case of aluminium alloy components and, more specifically, precipitation-hardened aluminium alloy components, the portion of supplied material deposited by cold spray typically has a high fragility and high internal tensions which are not wholly satisfactory in view of the use in the aeronautical sector.

In general, a significant lack of uniformity in terms of mechanical properties and microstructural characteristics is typically found between the substrate and the portion of supplied material deposited by cold spray. This lack of uniformity is undesirable in view of the intended use of the

components.

Furthermore, the adhesion quality between the portion of supplied material deposited and the substrate, although
5 generally better than other depositing techniques by thermal spraying, is generally limited.

Advantageously, according to the invention, the method for the repair of aluminium alloy components furthermore comprises the
10 step of subjecting the partially repaired component obtained from the cold spray depositing phase to a thermal treatment, thus obtaining a repaired component.

Said thermal treatment has the purpose of improving the
15 mechanical characteristics of the portion of supplied material, with the objective of reducing the lack of uniformity between portion of supplied material and substrate. Furthermore, said thermal treatment is conceived to improve the quality of the adhesion between the portion of supplied
20 material and the substrate.

Advantageously, according to the invention, a repaired component is subjected to a specific thermal treatment, the performance conditions of which have been selected according
25 to the composition and dimensional tolerances of said component to be repaired. Furthermore, it will also be possible to take account of the final use of the component, once repaired.

30 If the component to be repaired has sufficiently broad dimensional tolerances to allow for any deformations produced by the thermal treatment, the partially repaired component is advantageously subjected to the specific thermal treatment of the alloy, comprising:

35 - a first step of solubilisation followed by rapid cooling;
and

- a second step, following the first one, of precipitation.

If the component to be repaired is obtained from Al-Si alloys, type 355, 356 or 357, the first phase of solubilisation is preferably performed at a temperature from 500 to 580°C, more preferably from 530°C to 550°C, for a time in the range between 6 and 20 hours, while the precipitation phase is preferably performed at a temperature from 100 to 300°C, more preferably from 150°C to 230°C, for a time in the range between 3 and 12 hours.

10

If the component to be repaired is obtained from Al-Cu alloys, type 2014, 2618, 2024, the first step of solubilisation is preferably performed at a temperature from 400 to 600°C, more preferably from 460°C to 535°C, for a time in the range between 1 and 3 hours, while the step of precipitation is preferably performed at a temperature from 150 to 250°C, more preferably from 160°C to 200°C, for a time in the range between 8 and 20 hours.

Some examples are given below of the advantages that can be obtained with application of the complete thermal treatment of solubilisation and ageing on test pieces made of 357 aluminium-silicon alloy repaired by means of cold spray using 357 aluminium-silicon alloy powder as the supplied material:

25

Example 1a: Repair of rough components in 357 aluminium-silicon alloy already subjected to complete thermal treatment of solubilisation and precipitation (ageing).

The mechanical strength of the 357 aluminium-silicon alloy with complete thermal treatment, measured on cylindrical test pieces with diameter 9.0 mm according to ASTM B557, is on average 307 MPa.

30

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove of depth such as to reduce the resistant area to 49% of

the original area. The mean mechanical resistance measured on these test pieces was 179 MPa.

The test pieces with simulated defect were repaired by means of cold spray by depositing a layer of 357 aluminium alloy powder of thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the mechanical resistance measured on the repaired test pieces was on average 226 MPa. Analogous test pieces repaired by cold spray and subjected, after repair, to thermal solubilisation treatment at 540°C for 17.5 hours with cooling in water, followed by thermal treatment of precipitation (ageing) at 200°C for 7 hours, showed a mean mechanical resistance of 250 MPa, with an improvement of approximately 11% compared to the components that were not thermally treated.

Example 1b: Repair of rough components in 357 aluminium-silicon alloy already subjected to complete thermal treatment of solubilisation and precipitation (ageing).

The mechanical resistance of the 357 aluminium-silicon alloy completely thermally treated, measured on cylindrical test pieces with diameter of 9.0 mm according to ASTM B557, is on average 307 MPa.

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove with depth such as to reduce the resistant area to 33% of the original area. The mean mechanical resistance measured on these test pieces was 122 MPa.

The test pieces with simulated defect were repaired by means of cold spray depositing a layer of 357 aluminium alloy powder with thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from

the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the mechanical resistance measured on the repaired test pieces was on average 197 MPa. After repair by cold spray, a thermal treatment of solubilisation was performed at 540°C for 17.5 hours with cooling in water, followed by thermal treatment of precipitation (ageing) at 200°C for 7 hours; these treatments increased the mechanical characteristics of the repaired test pieces to mean values of 216 MPa, with an improvement also in this case of approximately 10% with respect to the components that did not undergo the thermal treatment.

Example 2a: Repair of rough non-treated (as-cast) components in 357 aluminium-silicon alloy.

The mechanical resistance of the non thermally treated (as-cast) 357 aluminium-silicon alloy, measured on cylindrical test pieces with diameter 9.0 mm according to ASTM B557, is on average 199 MPa.

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove with depth such as to reduce the resistant area to 49% of the original area. The mean mechanical resistance measured on these test pieces was 116 MPa.

The test pieces with simulated defect were repaired by cold spray depositing a layer of 357 aluminium alloy powder with thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the mechanical resistance measured on the repaired test pieces was on average 127 MPa. Analogous test pieces repaired by cold spray and subjected, after repair, to a thermal solubilisation treatment at 540°C for 17.5 hours with cooling in water, followed by a thermal precipitation (ageing) treatment at 200°C for 7 hours, showed a mean

mechanical resistance of 271 MPa, with an improvement of approximately 113% compared to the components that did not undergo the thermal treatment.

5 **Example 2b: Repair of rough non-treated (as-cast) components in 357 aluminium-silicon alloy.**

The mechanical resistance of the non thermally treated (as-cast) 357 aluminium-silicon alloy, measured on cylindrical test pieces with diameter 9.0 mm according to ASTM B557, is on
10 average 199 MPa.

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove with depth such as to reduce the resistant area to 33%
15 of the original area. The mean mechanical resistance measured on these test pieces was 75 MPa.

The test pieces with simulated defect were repaired by cold spray depositing a layer of 357 aluminium alloy powder with
20 thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the mechanical resistance measured on the repaired test pieces was on average 78 MPa. Analogous test
25 pieces repaired by cold spray and subjected, after repair, to thermal treatment of solubilisation at 540°C for 17.5 hours with cooling in water, followed by thermal treatment of precipitation (ageing) at 200°C for 7 hours, showed a mean mechanical resistance of 191 MPa, with an improvement of
30 approximately 145% compared to the components that did not undergo the thermal treatment.

The examples given above highlight the benefits of complete thermal treatment on rough components made of 357 aluminium
35 alloy repaired by cold-spray depositing.

As mentioned previously, the complete thermal treatment of solubilisation and ageing can entail deformations of the component, and it is therefore generally applied to rough components (e.g. castings or semi-finished products) where the dimensional tolerances allow for the deformations induced by the thermal treatment.

If, on the other hand, the component to be repaired has limited dimensional tolerances which do not allow for potential deformations by the thermal treatment, the partially repaired component is advantageously subjected to a thermal treatment comprising a single stress-relieving phase.

If the component to be repaired is obtained from Al-Si alloys, type 355, 356 or 357, the stress-relieving phase is preferably performed at a temperature from 80°C to 250°C, more preferably from 100°C to 200°C, for a time in the range between 3 and 10 hours.

If the component to be repaired is obtained from Al-Cu alloys, type 2014, 2618, 2024, the stress-relieving phase is preferably performed at a temperature from 80°C to 200°C, more preferably from 100°C to 180°C, for a time in the range between 3 and 20 hours.

Some examples are given below of the advantages that can be obtained with application of only stress-relieving thermal treatment on test pieces made of 357 aluminium-silicon alloy repaired by cold spray using 357 aluminium-silicon alloy powder as supplied material:

Example 3a: Repair of semi-finished or finished components in 357 aluminium-silicon alloy already subjected to complete thermal treatment of solubilisation and precipitation (ageing).

The mechanical resistance of the 357 aluminium-silicon alloy completely thermally treated, measured on cylindrical test pieces

with diameter 9.0 mm according to ASTM B557, is on average 307 MPa.

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove of depth such as to reduce the resistant area to 49% of the original area. The mean mechanical resistance measured on these test pieces was 179 MPa.

The test pieces with simulated defect were repaired by cold spray depositing a layer of 357 aluminium alloy powder of thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the mechanical resistance measured on the repaired test pieces was on average 226 MPa. Analogous test pieces repaired by cold spray and subjected, after repair, to thermal stress-relieving treatment at 125°C for 7 hours highlighted a mean mechanical resistance of 245 MPa, with an improvement of approximately 8% compared to the components that did not undergo the stress-relieving treatment.

Example 3b: Repair of semi-finished or finished components in 357 aluminium-silicon alloy already subjected to complete thermal treatment of solubilisation and precipitation (ageing).

The mechanical resistance of the 357 aluminium-silicon alloy completely thermally treated, measured on cylindrical test pieces with diameter 9.0 mm according to ASTM B557, is on average 307 MPa.

To simulate a defect to be repaired, the working section of some test pieces was re-machined, creating a circumferential groove with depth such as to reduce the resistant area to 33% of the original area. The mean mechanical resistance measured on these test pieces was 122 MPa.

35

The test pieces with simulated defect were repaired by cold spray

depositing a layer of 357 aluminium alloy with thickness sufficient to completely fill the circumferential groove. After removal of the excess layer from the working section of the test pieces, in order to restore the original diameter of 9.0 mm, the
5 mechanical resistance measured on the repaired test pieces was on average 197 MPa. After repair by cold spray, the performance of subsequent thermal stress-relieving treatment at 125°C for 7 hours increased the mechanical characteristics of the repaired test pieces to mean values of 263 MPa, with an improvement of 33%
10 compared to the components that did not undergo the stress-relieving treatment.

The method of the invention has particularly positive effects on the repaired components in terms of both improvement of the
15 mechanical properties of the portion of supplied material and in terms of adhesion of the portion of supplied material to the substrate.

In particular, with the method of the invention the internal
20 tensions in the portion of supplied material and at the interface with the substrate are reduced. Furthermore, the hardening phases are precipitated, improving and stabilising the structure of the portion of supplied material which is thus made as far as possible uniform and similar to that of the substrate. At the
25 same time, the method promotes the interdiffusion of lightweight elements at the interface, consequently improving adhesion between the portion of supplied material and the substrate.

In the condition in which the component to be repaired has
30 sufficiently broad dimensional tolerances to allow for any deformations introduced by the complete thermal treatment, the method of the invention has the particularly desirable effect, from the mechanical point of view and in terms of performance, of making the behaviour of the portion of supplied material very
35 similar to that of the substrate. In fact, the tensions due to the deformations inside the portion of supplied material are

completely annulled and the material substantially re-precipitates in the precipitation (ageing) phase, thus obtaining the maximum benefit in terms of mechanical characteristics and adhesion between the parts.

5

In any case, even when the component to be repaired has limited dimensional tolerances which do not allow for potential deformations caused by thermal treatment, or because it has already been thermally treated before the repair, the method of the invention produces a significant benefit. In fact, the thermal stress-relieving treatment is performed at temperatures and for times such as to favour a sort of ageing of the material, but not such as to cause phenomena of over-precipitation, which would result in unacceptable deterioration in the characteristics of the substrate base material.

15

With the treatment of the invention, in fact, the tensions inside the portion of supplied material are reduced and a precipitation of hardening phases is provoked in the same, thus minimising the differences with respect to the substrate base material (or the component to be repaired).

20

It should be noted that, on the basis of the previous studies performed on depositing of aluminium alloys by cold spray, such as those reported in the patent US 2009/0148622, it would appear not necessary to carry out thermal treatments after the depositing to obtain the required mechanical properties. Nevertheless, the method proposed in the present invention provides an undoubted improvement in the mechanical properties of the components.

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The patent US 6,905,728 cites the performance, after repair of high pressure turbine components by cold spray, of a process of vacuum sintering, followed by a process of hot isostatic pressing and then thermal treatment. It is evident that said thermal treatment has the main objective of restoring the properties of

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the material after the sintering and hot isostatic pressing processes rather than that of improving the characteristics of the material deposited by cold spray.

- 5 Lastly, the publication "Characterization of low pressure type cold spray aluminium coatings" by K. Ogawa, K. Ito, K. Ichimura, Y. Ichikawa and T. Shoji, Sendai/J explicitly cites the beneficial effect of an annealing treatment at 270°C for 9 hours on the ductility of the aluminium deposit applied by cold spray.
- 10 However, although this thermal treatment improves the ductility of the material, it has the drawback of drastically reducing the mechanical properties of the substrate and therefore cannot be conveniently used in practice in the sector of interest taken into consideration for the present invention.

CLAIMS

1. A method for repairing a precipitation hardened aluminium alloy component comprising the steps of:

a) cold spray depositing on said component to be repaired a portion of supplied material having a composition identical to that of said component to be repaired, thus obtaining a partially repaired component;

b) subjecting said partially repaired component to a thermal treatment, thus obtaining a repaired component, the conditions for performing said thermal treatment being selected as a function of the composition and of dimension tolerances of said component,

characterised in that said step b) of thermal treatment comprises:

c) a first step of solubilisation followed by cooling in water; and

d) a second step, following the first step c), of precipitation.

2. The method according to claim 1, wherein, if said component to be repaired is obtained from type 355, 356 or 357 Al-Si alloys, said first step c) of solubilisation is performed at a temperature from 500°C to 580°C for a time in the range between 6 and 20 hours, and said second step d) of precipitation is performed at a temperature from 100°C to 300°C for a time in the range between 3 and 12 hours.

3. The method according to claim 2, wherein, if said component to be repaired is obtained from type 355, 356 or 357 Al-Si alloys, said first step c) of solubilisation is performed at a temperature from 530°C to 550°C for a time in the range between 6 and 20 hours, and said second step d) of precipitation is performed at a temperature

from 150°C to 230°C for a time in the range between 3 and 12 hours.

4. The method according to claim 1, wherein, if said component to be repaired is obtained from type 2014, 2618 or 2024 Al-Si alloys, said first step c) of solubilisation is performed at a temperature from 400°C to 600°C for a time in the range between 1 and 3 hours; said second step of precipitation is performed at a temperature from 150°C to 250°C for a time in the range between 8 and 20 hours.

5. The method according to claim 4, wherein, if said component to be repaired is obtained from type 2014, 2618 or 2024 Al-Si alloys, said first step c) of solubilisation is performed at a temperature from 460°C to 535°C for a time in the range between 1 and 3 hours; said second step of precipitation is performed at a temperature from 160°C to 200°C for a time in the range between 8 and 20 hours.

6. A method for repairing a precipitation hardened aluminium alloy component obtained from type 355, 356 or 357 Al-Si alloys comprising the steps of:

a) cold spray depositing on said precipitation hardened 355, 356 or 357 Al-Si alloy component to be repaired a portion of supplied material having a composition identical to that of said precipitation hardened 355, 356 or 357 Al-Si alloy component to be repaired, thus obtaining a partially repaired precipitation hardened 355, 356 or 357 Al-Si alloy component;

b) subjecting said partially repaired precipitation hardened 355, 356 or 357 Al-Si alloy component to a thermal treatment, thus obtaining a repaired precipitation hardened 355, 356 or 357 Al-Si alloy component, the conditions for performing said thermal treatment being selected as a function of the composition and of dimension

tolerances of said precipitation hardened 355, 356 or 357 Al-Si alloy component, wherein step b) of thermal treatment comprises a step e) of stress relieving performed at a temperature from 100°C to 200°C for a time from 3 to 10 hours.

7. A method for repairing a precipitation hardened aluminium alloy component obtained from type 2618 Al-Si alloys comprising the steps of:

a) cold spray depositing on said precipitation hardened 2618 Al-Si alloy component to be repaired a portion of supplied material having a composition identical to that of said precipitation hardened 2618 Al-Si alloy component to be repaired, thus obtaining a partially repaired precipitation hardened 2618 Al-Si alloy component;

b) subjecting said partially repaired precipitation hardened 2618 Al-Si alloy component to a thermal treatment, thus obtaining a repaired precipitation hardened 2618 Al-Si alloy component, the conditions for performing said thermal treatment being selected as a function of the composition and of dimension tolerances of said precipitation hardened 2618 Al-Si alloy component, wherein step b) of thermal treatment comprises a step e) of stress relieving performed at a temperature from 100°C to 180°C for a time from 3 to 20 hours.